Thesis/
Reports
Heinen,
J.T.

LOAN COPY

gRISTARS

WESTFORNET
MONTHLY ALERT
Edition JAN 1983 F
Item No. 245
File VF 82 1139

RR-U2-04256

A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

February 1982

NATIONWIDE FORESTRY APPLICATIONS PROGRAM
Renewable Resources Inventory Project

Cooperative Research Report NFAP-292

THE APPLICATION OF REMOTE SENSING TO SITE- AND SPECIES-SPECIFIC WILDLIFE HABITAT ANALYSIS

Cooperative Agreement No. 13-1134

Virginia Polytechnic Institute
and State University
Blacksburg, Virginia 24061

USDA Forest Service

82 1139

PROJECT SUPPORTED BY

Nationwide Forestry Applications Program
Renewable Resources Inventory Project
Houston, TX

February 1982

Cooperative Agreement No. 13-1134

Remote Sensing Research Report 82-2

The Application of Remote Sensing to Site- and Species-Specific Wildlife Habitat Analysis

by

Joel T. Heinen 1/

Roy A. Mead 2/

1/ Graduate Research Assistant, Department of Forestry, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.

2/ Assistant Professor.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NFAP-292; RR-U2-04256		

4. Title and Subtitle

The Application of Remote Sensing to Site- and Species-Specific Wildlife Habitat Analysis

5. Report Date
February 1982

6. Performing Organization Code

7. Author(s)
J. T. Heinen and R. A. Mead
Virginia Polytechnic Institute and State University

8. Performing Organization Report No.
82-2

9. Performing Organization Name and Address
School of Forestry and Wildlife Resources
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

10. Work Unit No.

11. Contract or Grant No.
13-1134

12. Sponsoring Agency Name and Address
U.S. Department of Agriculture, Forest Service, Nationwide Forestry Applications Program, 1050 Bay Area Boulevard
Houston, Texas 77058 (Technical Monitor: J. R. Bell)

13. Type of Report and Period Covered
Technical Report

14. Sponsoring Agency Code

15. Supplementary Notes
The Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing is a joint program of the U.S. Department of Agriculture, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration (U.S. Department of Commerce), the Agency for International Development (U.S. Department of State), and the U.S. Department of the Interior.

16. Abstract

The major objective of this study is to test a proposed index designed to measure spatial relationships as an index of wildlife habitat quality. The index is species specific and is a function of interspersion, juxtaposition, and the presence of exclusion factors within the area, and for the species in question.

A sensitivity analysis is conducted to determine how changes in various parameters affect the index value. These parameters include: cell size, cell shape, number of cover types, weighing factors, and classification accuracy.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Remote sensing Wildlife habitat	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	89	

*For sale by the National Technical Information Service, Springfield, Virginia 22161

TABLE OF CONTENTS

		Page
1	Preface with Acknowledgments	i
2	Introduction	1
3	Thesis Working Plan	4
4	Draft 1 - Wildlife Application	34
5	Draft 2 - Forestry Application	53
6	Summary	68
	Appendix I	69

PREFACE

The authors would like to thank Drs. G. H. Cross, R. H. Hokans, H. E. Burkhart, and P. T. Bromley of the VPI School of Forestry and Wildlife Resources for critical reviews of sections of this report. Special thanks go to David Cook, Wildlife Biologist, San Juan National Forest, for his various comments and recommendations.

The Application of Remote Sensing to Site- and Species-Specific Wildlife Habitat Analysis

INTRODUCTION

This report consists of a description of the two major areas of work conducted on this project during 1981. It includes a thesis working plan and drafts of three papers describing other applications of these indices.

The thesis working plan was presented to the graduate faculty of the School of Forestry and Wildlife Resources, Virginia Polytechnic Institute and State University, and was accepted in June, 1981. It includes a literature review of remote sensing applications to wildlife habitat analysis, and a procedures section which describes the specific hypotheses which will be tested on various parameters used in Mead's indices. These hypotheses include testing the effects of changing

1) the number of cover types,
2) the classification accuracy,
3) the cell size,
4) the cell shape,
5) the weighting factors,

of the input data on the calculation of interspersion, juxtaposition, and spatial diversity as described by Mead. Areas located within the

Rampart Hills Quad, San Juan National Forest, Colorado, may be used to test the first, second, and fifth hypotheses above. Tests of cell size and cell shape (hypotheses 3 and 4 above) will be conducted using artificial cover type maps as input. The statistical testing procedure follows that described by Congalton (1981).

After the testing procedures are complete, a manual can then be written which describes appropriate classification accuracy, the proper use of weighting factors, and the specificity (e.g., level 1, 2, etc.) of type categories used as input.

The other two tests to be conducted, those of cell size and cell shape, are less important for digital satellite data, as these parameters are for the most part fixed by the system. However, they become important when aerial photography or existing cover type maps are used as input, as a potential user then has an option in choosing appropriate grid cell sizes or shapes. The tests to be completed concerning these two parameters will not lead to a judgment concerning optimal cell size or shape in analyzing habitat for particular species. They will statistically compare the use of a variety of cell sizes and shapes on the calculation of each index. The actual shape or size of the grid cells used (when there is an option) is thus left to the discretion and expertise of potential users of this system.

The three papers included in this report represent drafts which were prepared for professional journals. They are presently in the review process. The first one describes the use of the indices in a diverse area which was type-mapped from large scale color infrared aerial photography. This paper describes manual calculation of the indices over small areas, and is written for professional wildlife biologists.

The second draft included here describes the simulation of different sizes and shapes of clearcuts and their predicted effects on deer habitat in an 1800 acre area in the San Juan. This paper illustrates the potential of these indices for use as a subroutine in a more comprehensive timber harvesting model. This would aid in multiple use forest planning and allow agencies to meet the requirements of some recent legislation which mandates that wildlife habitat must be considered in forestry practices on all federal lands.

The third paper included in this report consists of a description of one of the applications of the system proposed by Mead on various wildlife species in the San Juan (Appendix 1). This paper was previously published (Heinen et al. 1981). Such demonstrations are important in that the results can be reviewed by local wildlife biologists who can provide feedback based on experience concerning the appropriateness of the indices in assessing habitat.

Introduction

As human population densities and demands for land resources increase, so does the need to develop effective means of evaluating wildland resources and wildlife habitat in areas designated, in part, for this purpose. This need was specifically addressed in the Resources Planning Act of 1974 (Mead, et al., 1981). As a result, multiple use agencies within the United States have recently implemented procedures of evaluation and inventory of natural areas. For example, the Forest Service released its preliminary Wildlife Habitat Management Handbook in 1971, which includes habitat requirements of selected wildlife species to be used in selecting a Featured Species for each tract of land managed by the Agency in the Southern Region. The U.S. Geological Survey has addressed similar concerns in its implementation of a wetland habitat classification scheme (Stewart, et al., 1980).

Various remote sensing technologies have gained wide acceptance in the field of wildlife management (Colwell, 1978). Such technologies have been applied to both population and habitat inventories. Some problems have been addressed in habitat inventories and research is needed in the refinement of habitat analysis. Despite this, operational habitat analysis systems relying on remotely sensed information have been implemented by Kansas Forestry, Fish and Game Commission (1976), the Texas Department of Parks and Recreation (Frye, 1978) and the Tennessee Valley Authority (Davis, 1980); to name a few.

Many State and Federal agencies have the responsibility of managing large areas of land for multiple use. This elucidates the utility of

computer evaluation of data collected to assess the status of such areas. In many instances, the advent of computer technology has made large scale land use inventories and habitat evaluation feasible. The computer aided system called IMGRID, for example, was developed at Harvard (Sinton, 1976), and has proven particularly effective in multiple use area evaluation. It is presently used by T.V.A., where it has been applied to wildlife habitat evaluation (Davis, 1980).

The use of various remote sensing procedures coupled with computer technology has facilitated great strides in habitat evaluation. This does not, however, eliminate the need for ground truths (Carter, Garrett, 1977). The ultimate decision of the goodness of an area for any particular purpose rests on an educated land use manager. This reflects on possible errors in classification of cover types by landsat, or interpretation errors by people working with aerial photography. These factors stress the importance of accuracy measurements in studies relying on remotely sensed information systems (Frentress and Frye, 1975). The potential sources of error should therefore be addressed in any habitat assessment procedure.

The main assumptions underlying any system designed to assess habitat is that all the land under consideration has some wildlife habitat value, and that this value can be quantified (Daniels and Lemaire, 1974). Indices developed to assess habitat should ideally produce consistent results with an acceptable margin of error, compare well with other indices designed to assess similar relationships, and be constructed so as to be easily and economically useful to practicioners of land management.

The Forest Service is now legally mandated to maintain diversity of plant and animal communities in accordance with multiple use objectives. This is to be considered throughout the planning process (Federal Registrar, 1979). The agency is therefore interested in testing economic and expedient methods of measuring diversity in natural communities.

The major objective of this study is to test a proposed index (Mead, et al., 1981) designed to measure spatial relationships as an index of wildlife habitat quality. The index is species specific and is a function of interspersion, juxtaposition, and the presence of exclusion factors within the area, and for the species in question (see Appendix I).

A sensitivity analysis will be conducted to determine how change in various parameters affect the index value. These parameters include: cell size, cell shape, number of cover types, weighing factors, and classification accuracy.

Literature Review

Vegetation Classification

Two major problems inherent in vegetative classification schemes is whether classification is appropriate, and under what conditions may the use of any scheme be warranted. Two major conflicting theories regarding these problems were described by McIntosh (1967). These include:

1) The Community Concept of Vegetation, which asserts that vegetation is composed of well-defined units which can be grouped naturally into communities. Classification schemes in this case would follow a natural order.

2) The Continuum Concept of Vegetation, which states that plant communities are not discrete or differentiable. Any classification scheme would in this case be arbitrary.

It is possible that in presettlement times, the structure of plant communities may have more closely approximated that expected by the Continuum Concept. For the purposes of this study, however, it shall be assumed that classification is appropriate and communities are definable, and therefore the Community Concept is valid. This assumption is a direct result of land management and other activities imposed on land resources by modern man. Forest Service land, for example, may readily be classified by age of stands, clearcuts, and burning activities. This may be accomplished by conducting site observations, or by reviewing the agencies' management prescription records for the areas under consideration.

Despite the potential sources of error in vegetative classification, various proposed systems have been proven effective. Vegetative type maps developed by the state of Texas, for example, have been used to determine acreages of various cover types and changes in land use. There is a potential in this system for predicting future changes in land use, and the system has been used as an aid in management decision making (Frye, et al., 1978). Type-mapping has been conducted extensively on the Great Dismal Swamp, and Carter and Garrett (1977) cite the utility of using Landsat and color infra-red photography in monitoring future vegetative changes in this 84,890 hectare wildlife refuge. In both the aforementioned studies, the relative ease of classification was due probably to habitat alteration by human means. For reasons previously mentioned, classification may prove to be more difficult in large, unaltered ecosystems.

The method of classification is the major concern in any study regarding the distribution of vegetative types. Classifications systems must be developed which are biologically meaningful. This criteria may vary greatly depending on the nature and location of the study.

Spatial Distribution of Habitat

Various concepts concerning the spatial distribution of habitat have been discussed in reference to their importance for wildlife. Included in these are the edge effect, ecotone, zone of influence, interspersion, and juxtaposition. Each is presented individually within this

section.

The edge effect describes a response by organisms to community junctions (Leopold, 1936). This is defined by Odum (1971) as the "tendency for increased variety and density at community junctions." This definition is very general, and the effect itself may vary greatly between species. The edge effect is most pronounced among animals with relatively low mobility and diverse ecological requirements (Leopold, 1936). Some more recent publications indicate that species diversity for various taxa is directly proportional to habitat diversity. These include studies by Pianka (1966) on desert lizards, and Recher (1969) on various bird species. Leopold (1936) explains game abundance as a consequence of edge. He further clarifies this by stating that game abundance should increase in situations where various food and cover types can be found in close proximity. This clarification is warranted, as edge, in itself, is probably not the key factor. The occurrence of the biological requirements for a species within a realtively small area is the main concern. Animals must be capable of reaching such requirements daily, or nearly so (Leopold, 1936).

We may expect any natural community to have some potential for the maintenance of wildlife, but the degree to which this is true may vary greatly in different plant communities, and with different wildlife species. An animal may be limited to more specific areas within its broad geographical range by various ecological factors. It is the combination of these factors which defines the animal's habitat (Rekas, 1978).

The term ecotone, commonly discussed in combination with the edge effect, has been loosely applied but refers generally to a gradation be-

tween two plant communities (Odum, 1971). This transition may take on a variety of characteristics depending on the environmental characteristics of an area, or the amount of human disturbance. Odum (1971) describes forest edges as being one of the most important ecotones for human concerns. This statement may reflect the fact that large, well-defined forest edges are usually the result of human activities such as timbering practices and agriculture. A similar, but much less pronounced natural phenomenon is the creation of light gaps in forest communities. It is probable that few natural cases exist in which ecotones are as well-defined as those created by human disturbance, though some exceptions occur (Spurr, Barnes, 1973).

Giles (1978) describes the concept of 'zones of influence' emanating from a habitat edge or point habitat. Some examples of the latter include patches of food or cover, or water sources in otherwise relatively homogenous areas. He defines this term as "a distance over which wildlife is attracted, from which views are possible, or from which behavior may emanate". It can readily be pointed out that the zone of influence surrounding any edge depends largely on the mobility of the organism in question. This concept and that of the edge effect are closely interrelated.

Interspersion and juxtaposition are terms which in their usual context refer to measurements of the spatial relationships of habitat types. Giles, (1978), refers to interspersion as a measurement of the spatial intermixing of habitat types, and to juxtaposition as some measure of the proximity of different habitat types. Thus an area of high interspersion would be characterized as having a good distribution

of cover types in space, while an area of high juxtaposition would be one in which different cover types are found adjacent to one another frequently. Most attempts at species specific juxtaposition measurement include relative weighting factors assigned by the importance of the adjacency of two cover types for the species in question (Roller, 1978). Interspersion and juxtaposition within an area may vary in a directly proportional manner, but this is not necessarily the case. Species specific juxtaposition measurement may be low in an area of high interspersion if the weighting factors of the adjacent habitat types are low. The total habitat quality of an area for any species can thus be considered a function of both juxtaposition and interspersion.

Habitat Assessment Procedures

Williamson, et al. (1978) define habitat evaluation as a "process of assigning a qualitative rating to a given area based on how well that area meets the requirements of the wildlife species under consideration". Habitat analysis may be divided into two broad categories: site and non site-specific. Site-specific analysis includes that in which classification is complete throughout the area in question, while non site-specific analysis includes analysis which attempts to provide gross estimates of habitat types, without addressing all components within an area (Meyer, 1978).

Various procedures have been utilized in assessing habitat. There is an increasing trend in both public and private sectors in the use of remote sensing in site-specific analyses (Meyer, 1978). Many of these analyses are not uniform in that they test different relationships with varying degrees of success. Roller (1978) devised a rather successful

technique for obtaining habitat conditions for White-tailed Deer on the University of Michigan's George Reserve. This consisted of evaluating trends for habitat changes based on interpretation and comparisons of old and new aerial photos. In many situations, however, this procedure may be impractical. Accurate records of the George Reserve are available due to the amount of research conducted in this two square mile enclosure. This may not be the case over many broad areas. In other studies, computer simulation of vegetative changes have been used to predict future vegetational characteristics (Williamson, et al., 1978).

Ffolliet and Rasmussen (1978) developed a habitat ranking (HABRAN) procedure designed to estimate the impact of management decisions on available habitat. The authors include species response functions which are graphs of the potential habitat rating vs. percent crown closure, and they indicate that the functions are both species and ecosystem dependent. Correlations between crown closure and habitat potential are important, but this fails to address the multitude of other spatial variables which may be equally pertinent. This work may prove most adequate in providing gross estimates of suitability in areas with lumbering activities. Habitat data bases need not include all environmental factors within an area to be useful (Russell, et al., 1980). Economic constraints may, in some cases, put limitations on data collection. It is however, an oversimplification to rank habitat by one parameter alone.

Rekas (1978) provides guidelines for habitat analysis. His criteria include:

Identification of habitat requirements for the species in question.

Location of these requirements within the study area.

Preparation of map overlays showing the extent of each factor in the study area.

Preparation of composite map.

Verification of composite map.

These procedures are generally consistent with those used in other studies. However, the use of a resource within an area by any particular animal may change depending on the nature of the resource. For example, if one assumes that White-tailed Deer require water, the nature of the water source would be of prime importance in determining its suitability for the deer in question. The water may be stagnant vs. free-flowing, seasonal vs. permanent, or brackish vs. fresh, and these variables may alter the importance of the water source for deer. A more thorough analysis would include the attempt to quantify the habitat potential for the species in the area in question. This may include the assignment of relative rankings of various resources within an area, depending on their importance for the species in question. Recognition and numerical assignment of exclusion factors may further improve habitat analyses.

Davis (1980) describes the use of IMGRID by the T.V.A. in determining fall and spring habitat suitability for Wild Turkey. Those habitat components of most importance for the turkey must first be recognized and assigned weights. The components include hard mast, soft mast, greens, insect availability (important in spring only), presence of surface water, escape cover, and roosting sites. Proximity analyses were conducted which measured distance to water and distance to roosting sites. The distances over which turkey will travel to these requirements are assumed to vary seasonally. All components must be located within one square

mile. Weights were then assigned on a relative scale increasing with their importance to the turkey. The implementation of the IMGRID program then sums all components within each cell. Those cells with higher final values are thus designated as representing areas of better turkey habitat. This method is reported as being very effective.

Katibah and Graves (1978) describe another method used to designate turkey habitat which involves the recognition of vegetative associations using Landsat II imagery. Areas known to contain viable turkey populations were used as training sets so the researchers could learn to recognize the vegetative associations which the turkey preferred. This is a relatively inexpensive method but can only produce rough approximations in designating good habitat when compared to the method previously described. The ability to define those components most important to the animal in question is of prime importance in habitat evaluation (Davis, 1980). This ability may diminish using only small scale Landsat imagery.

Pettinger et al. (1978) describe the Habitat Evaluation Procedure (H.E.P.) developed by the Fish and Wildlife Service. Curves were presented in this study which consist of environmental parameters on the x-axis (such as distance to cover or water, forage availability, etc.), and a Habitat Suitability Index (HSI) ranging from 0 to 1 on the y-axis. The product of the habitat quality (HSI) and the habitat quantity (area) produces the total amount of Habitat Units (H.U.) for each vegetation type in the study area. The H.U.'s for elk and Sage Grouse were determined by measuring the important parameters from high altitude color infra-red photography (scales of 1:15,000 to 1:20,000 were used). One problem with this study is that the habitat value for Sage Grouse using remotely sensed information alone was inconsistent with that obtained from the

total inventory data sets, which combined both remotely sensed data sets as well as ground inventory data sets. This discrepancy presumably was the result of some habitat parameters for grouse being inadequately measured by such small scale photography. The comparative values for elk were consistent between data sets. Larger scale photography and ground truths may therefore be increasingly important in designated habitat for small vs. large game.

The location and designation of potential prairie dog habitat is described by Rekas (1978). Information on slope, soil characteristics, and vegetation associations were used. The vegetation was interpreted from 1:20,000 black-and-white photography. Slope and soil characteristics were obtained from soil survey maps of the area. Ninety-three percent of existing prairie dog colonies were located within areas designated as potential prairie dog habitat. In this case, the soil characteristics are probably the major factor in habitat identification for this small burrowing mammal. Also, the social structure of the prairie dog (large colony sizes) may permit easier identification of habitat than is the case with many other small animals. This illustrates the importance of having knowledge of many aspects of a species biology before effective habitat assessment is possible.

The Forest Service is attempting to meet the requirements of timber and wildlife in national forests of the Southern Region with the implementation of the featured species program (Holbrook, 1974). The biological requirements of the featured species in an area are used in part to determine the silvicultural practices to be used on the unit. Detailed descriptive analyses are available from the Forest Service which specify habitat requirements of game animals in different regions (USDA Forest Service, 1971.

Various edge indices have been proposed in the recent wildlife literature. Schuerholz (1974) describes a method of determining the total edge in an area by using the total number of edge points encountered on transects drawn over aerial photographs. The transects may be horizontal, vertical or radial lines. The radial lines produced the highest correlation between edge length on the photo (x-axis, in cm.) and the total number of edge points (y-axis).

Morrison (1972) describes an edge index determined by dividing the sampling area into a grid and drawing diagonals within each cell. The edge index (I) can be calculated by counting the number of cover changes along the diagonals, and is expressed as the number of cover type changes per unit area.

There is unfortunately a dearth of information on the relationship of total edge in an area to animal populations the area may support (Taylor, 1977). We may expect an increase in the number of species in areas with greater amounts of edge (Odum, 1971), but for reasons previously discussed, edge in itself yields little information on habitat quality for most species (see section on Spatial Distribution of Habitat).

Roller (1978) used edge relationships to calculate juxtaposition. This was accomplished by determining the linear distance associated with different kinds of edge, and multiplying this distance by an edge weighting factor. The product is then divided by the total amount of edge occurring in an area. This index is probably more realistic than total edge alone, as it allows the weighting of various edge combinations depending

on the importance of the edge type for the species in question.

Edge is, of course, only a linear relationship, and habitat evaluation studies should focus primarily on area. Roller (1978) included a shape factor which he determined by dividing the edge length by $2\sqrt{\text{Area } \pi}$. This is used to normalize the shape of the significant cover types to that of a circle. This procedure, however, can only yield approximate analysis and the error margin would increase as more cover types in an area deviate from circular form.

Other spatial considerations in habitat analysis include the size and shape of grid cells used to delineate an area. The mobility and home range size of an organism should ideally be used in determining grid cell size. Shape may be important if different shaped cells produce different results in calculating interspersion. Hexagonal cells have been effectively used in some habitat studies (Keller, et al., 1978), and discussed in other publications (Giles, 1978). There have been no studies to my knowledge which compare hexagonal or triangular cells with square cells in the calculation of interspersion or juxtaposition. Most studies employ grids with square cells apprently as a matter of convention.

Summary

Much recent work has been focused on the development of habitat assessment procedures. Most of these procedures, however, contain various problems and are not equally effective in their application in assessing habitat for various organisms. There exists a great need to develop procedures which are general enough to be applied to many wildlife species, and specific enough to yield meaningful results for any single species in any area. Factors of great importance include the nature of the vegetation in an area, the importance of respective vegetative types, and various aspects of the species' biological requirements.

Procedures

This study will test the effects of changes in cell size, cell shape, classification accuracy, relative weighting factors and the number of cover types used in the calculation of the interspersion, juxtaposition, and spatial diversity indices described by Mead et al., (1981). See Appendix I for a listing of these indices.

Input Data

Input Data may be generated from a variety of sources including existing cover type maps, aerial photo-mosaics, landsat imagery, and fictional cover type maps using artificial data (cover types). The procedure includes overlaying the source with a grid cell system drawn on acetate or a light grade paper, and coding digits which represent the predominant cover type into each cell. The digital data may then be coded into the computer. The implementation of the Wildint 2 program is then used to generate digital maps representing the class of interspersion, juxtaposition, and spatial diversity for each cell. The classes which thus far have been used include low (0 - 0.3), medium (0.3 - 0.6), and high (0.6 - 1.0) for each index, and can be designated with the digits 1, 2, and 3, respectively.

Testing the Effects of Changing Cell Size on the Proposed Indices

The hypothesis that changing cell size does not significantly change the resultant interspersion, juxtaposition, and spatial diversity maps may be tested by generating these maps from a source cover type map coded on a square grid cell system. The cell dimensions may then be linearly decreased by one half both vertically and horizontally, resulting in cells which are one quarter the area of the original cells. Using the original cover type map, the cover type data may then be coded onto the grid system containing the smaller sized cells, and maps of the three indices may then be generated from this data. This procedure may be repeated with a grid system containing larger cells obtained by doubling the original cell size linearly both horizontally and vertically. The resultant cells are thus four times the area of the original cells.

Similarity matrices may then be generated from the maps for each index between the original (base) cell size vs. those generated using the smaller cell size, and between the maps generated using the base cell size vs. those generated using the larger cell size. The implementation of the KAPPA program (see p. 22) may then be used to determine whether the two similarity matrices generated for each index produce significantly different results. In this case the null hypothesis that changes in cell size does not significantly change the resulting maps for each index (or any index) would be rejected.

Testing the Effect of Changing Cell Shape on the Proposed Indices

The use of hexagonal cells has been discussed recently in reference to cover type mapping (Giles, 1978, Keller, 1978). However, there are no studies to my knowledge which compare the effects of different shaped grid cells on the calcuation of juxtaposition, interspersion or spatial diversity.

The hypothesis that there is no significant difference between interspersion, juxtaposition, or spatial diversity maps generated by using different shaped cells may be tested by first calculating similarity matrices for each index between test sets (those computed originally using hexagonal or triangular cells) and a base set (computed using conventional square cells). Care must be taken to cover the same amount of area using the three different shaped cells so as to eliminate potential differences resulting from changes in cell size. The matrices may then be compared and tested for significant differences by the implementation of the KAPPA program. When using different shaped cells, the dividends must be changed in order to maintain the relative scale, which ranges from 0 to 1. In computing the interspersion factor in the spatial diversity index using hexagonal cells, for example, the total number of cover type changes must be divided by 6 as there are six sides and no corners which represent potential changes in cover type. For a complete listing of the calculation of the three indices, respectively, using triangular and hexagonal cells, see Appendix II.

Testing the Effects of Changes in Classification Accuracy on the Proposed Indices

The hypothesis that various levels of classification accuracy do not significantly change maps generated using the proposed indices may be tested by first calculating similarity matrices generated for each index from a base map vs. those generated from a map which is 70% similar to the base map, and a map which is 90% similar to the base, respectively. The implementation of the KAPPA program may be used to test whether there is a significant difference between the two error matrices. If this is the case, the less similar map may then be increased in similarity in reference to the base map, and the procedure may be repeated until no significant difference is found between the two resulting error matrices. In each case, the matrices to be compared include that obtained by the comparison of the base map vs. the map which is 90% similar to the base, and that obtained by comparing the base map with the map which is <90% similar to the base, for each index, respectively. The point at which no significant difference is observed between the two matrices represents the threshold above which the calculation of the respective indices is not affected by classification accuracy.

Testing the Effects of Changes in Relative Weighting Factors on the Calculation of Juxtaposition and Spatial Diversity

Qualitative weighting factors are used in the calculation of juxtaposition and spatial diversity (the latter being partially a function of the former - see Appendix I). The choice of the weighting factors may be of critical importance in the use of these indices.

The hypothesis that changes in relative weighting factors does not affect the resultant juxtaposition and spatial diversity maps may be tested by first computing a similarity matrix between a map using a certain set of weighting factors (base) vs. a map generated by using consistently lower weighting factors for juxtaposition and spatial diversity. This may be repeated by comparing the base with a map generated by using consistently higher weighting factors. The implementation of the KAPPA program can again be used to test for a significant difference between the two error matrices. By repeating this process continually changing the weighting factors, a threshold above or below which changes in weighting factors do not result in significant changes in the juxtaposition and spatial diversity maps can be determined.

Testing the Effects of Changing the Number of Cover Types on the Proposed Indices

The hypothesis that an increase or decrease in the number of cover types does not affect the resulting maps of the three respective indices may be tested by calculating similarity matrices for each index of a base map vs. a map derived by using more cover types and between the base vs. a map computed by using less cover types. The KAPPA program can again be used to test whether there are significant differences between matrices. By the repetition of this process, thresholds may be determined above or below which the number of cover types does not significantly alter the resultant maps for each index, respectively. For this phase of the work, data sets must be used in which classification levels can be increased and decreased, while maintaining the same level of accuracy. For the same data set, the specificity of classification is thus being tested for potential differences in interspersion, juxtaposition, and spatial diversity.

Computer Programs to be Used

Both the Wildint 2 and KAPPA programs which are used in each phase of this study are fully operational. They have already been used on limited data sets. The Wildint 2 program, written by Steven Prisley, is designed to create interspersion, juxtaposition, and spatial diversity maps as described by Mead et al., (1981). The KAPPA program, rewritten and documented by Russell Congalton, is designed to test for significant differences between similarity matrices using the statistic as described by Bishop et al., (1975).

Another program may be developed in the near future which will automatically compare cellularized data, cell by cell, to provide similarity matrices as input to the KAPPA program. This has thusfar been done by hand and it is an extremely time consuming and laborious process.

Summary

If the indices described by Mead et al., (1981) are to be operational, practical suggestions must be made to potential users as to the limitations of these indices in reference to the effects of changing various parameters on the maps which the Wildint 2 program produces. This study is designed to measure the effects of changing some of these parameters. When all phases are complete, suggestions may then be made concerning cell sizes, weighting factors, classification accuracy and classification specificity of the input data, in order to hopefully make the resultant interspersion, juxtaposition, and spatial diversity maps more biologically meaningful for the organisms in question, as well as more readily usable by practitioners of wildlife management.

Bibliography

Bishop, Y., S. Fienberg, and P. Holland. 1975. Discrete Multivariate Analysis: Theory and Practice. M.I.T. Press. Cambridge, MA. 575 pp.

Carter, V., and M. K. Garrett. 1977. Contribution of Remote Sensing to Habitat Evaluation and Management in a Highly Altered Ecosystem. Forty-second N. Amer. Wildl. Conf.

Colwell, R. N. 1978. Overview of Remote Sensing and Its Applications to Wildlife Management. Pecora IV. N.W.F. Scientific and Technical Series 3.

Daniels, C. S. and R. J. Lemaire. 1974. Evaluating Effects of Water Resource Developments on Wildlife Habitat. Wildlife Society Bulletin 2(3): 114-118.

Davis, S. B. 1980. IMGRID as a Tool for Wildlife Planning. U.S.D.A. Forest Service. Resources Evaluation Newsletter. Technical Article #1. Nov. 1980.

Federal Registrar. 1979. Part 219 - Planning. Vol. 44, No. 181. Sept. 17.

Ffolliott, R. F. and W. O. Rasmussen. 1978. Use of Remote Sensing Data to Interactively Simulate Wildlife Habitat Quality. Pecora IV. N.W.F. Scientific and Technical Series 3.

Frentress, C. D. and R. G. Frye. 1975. Wildlife Management by Habitat Units -- a Preliminary Plan of Action. In Proceedings of the NASA Earth Resources Survey Symposium. Houston, TX.

Frye, R. G., K. Brown, C. D. Frentress, D. M. McCarthy, C. A. McMahan, and S. Anderson. 1978. Production of Vegetation Type-Maps from Landsat Digital Data. Pecora IV. N.W.F. Scientific and Technical Series 3. (57-64).

Giles, Jr., R. H. 1978. Wildlife Management. W. H. Freeman and Company. San Francisco.

Holbrook, H. L. 1974. A System for Wildlife Habitat Management on Southern National Forests. Wildlife Society Bulletin, 2(3): 119-223.

Kansas Forestry, Fish and Game Commission. 1976. Development of a Statewide Habitat Inventory. Pittman-Robertson Rep., Proj. W-42-R, Valley Falls, KS. 44 pp.

Katibah, E. F. and W. C. Graves. Remote Sensing - Aided Assessment of Wild Turkey Habitat. Pecora IV. N.W.F. Scientific and Technical Series 3.

Keller, J. F., D. Heimbuch and M. Richmond. 1978. A Method of Horizontal Habitat Quantification for Use in Open Canopy Communities. Pecora IV. N.W.F. Scientific and Technical Series 3.

Leopold, Aldo. 1936. Game Management. Charles Scribner's Sons. New York, London.

McIntosh, R. P. 1967. The Continuum Concept of Vegetation. Bot. Rev. 33: 130-187.

Mead, R. A., T. Sharik, S. Prisely, and J. T. Heinen. 1981. A Computerized Spatial Analysis System for Assessing Wildlife Habitat from Vegetation Maps. Tech. Paper. Am. Soc. of Photogr. 47th Annual Meeting. 212-220.

Meyer, M. P. 1978. Application of Remote Sensing Data for Site-Specific Wildlife Habitat Analysis in the United States. Pecora IV. N.W.F. Scientific and Technical Series 3.

Morrison, J. A., and J. C. Lewis (eds.). 1972. Proceedings of the First National Bobwhite Quail Symposium. (Pgs. 158-164).

Odum, E. P. 1971. Fundamentals of Ecology. W. B. Saunders Co.

Pianka, E. R. 1966. Complexity, Desert Lizards, and Spatial Heterogeneity. Ecology 47: 1055-1059.

Pettinger, L. R., A. Farmer, M. Schamberger. 1978. Quantitative Wildlife Habitat Evaluation Using High Altitude Color Infrared Aerial Photographs. Pecora IV. N.W.F. Scientific and Technical Series 3. (pp. 335-345).

Recher, H. 1969. Bird Species Diversity and Habitat Diversity in Australia and North America. Am. Nat. 103: 75-80.

Rekas, A. M. B. 1978. Inventory of Wildlife Habitat: An Approach and Case Study. Pecora IV. N.W.F. Scientific and Technical Series 3.

Roller, Norman E. G. 1978. Quantitative Evaluation of Deer Habitat. Pecora IV. N.W.F. Scientific and Technical Series 3.

Russell, K. R., G. L. Williams, B. A. Hughes, and D. S. Walsworth. 1980. Wildmis - A Wildlife Mitigation and Management Planning System - Demonstrated on Oil Shale Development. U.S.D.A.F.W.S. Western Energy and Land Use Team. Contract No. 14-16-0008-2016.

Schuerholz, G. 1974. Quantitative Evaluation of Edge From Aerial Photographs. Jr. Wildlife Mgt. 34(4): 913-920.

Sinton, D. F. 1976. An Introduction to IMGRID - an Information Manipulation System for Grid Cell Data Structures. Dept. of Landscape Architecture, Harvard Graduate School of Design. Cambridge, MA.

Spurr, S. H. and B. V. Barnes. 1973. Forest Ecology. (2nd Edition). The Ronald Press Company, New York.

Stewart, W. R., V. Carter, P. D. Brooks. 1980. Inland (Non-tidal) Wetland Mapping. Photogr. Eng. and Rem. Sensing. Vol. XLVI, #5. pp. 617-630.

Taylor, M. W. 1977. A Comparison of Three Edge Indexes. Wildl. Soc. Bull. 5(4): 192-193.

United States Department of Agriculture Forest Service. 1971. Wildlife Habitat Management Handbook. Southern Region. FSH 2609.23R.

Williamson, Jr., J. F., J. B. Whelan, and R. A. Mead. 1978. A Computerized Wildlife Habitat Information System.

APPENDIX I

The Calculation of Interspersion, Juxtaposition, and Spatial Diversity Using Square Cells

Interspersion

2	3	1
2	1	1
3	3	1

Is = 5

The center cell has 5 adjacent cells with disimilar cover types. The value of interspersion is therefore 5.

Juxtaposition

2	3	1
2	1	1
3	3	1

Edge Type	Quantity	Quality	Total
1/2	3	.2	.6
1/3	5	.6	3.0
2/3	0	.4	0.0

Jx Index = 3.6

In the calculation of juxtaposition, diagonal edges count as 1, while vertical or horizontal edges count as 2. The quality value for each edge type must be determined for each species. This is then multiplied by the quantity to determine the totals, and the sum of the totals is the juxtaposition index for a particular species, and for that particular cell.

Spatial Diversity

The spatial diversity index is a function of interspersion, juxtaposition and any number of exclusion factors.

$$Sd_A = [(\sigma_A \frac{Is}{8}) + (\alpha_A \frac{Jx}{12})] [1_A \times 2_A \times 3_A]$$

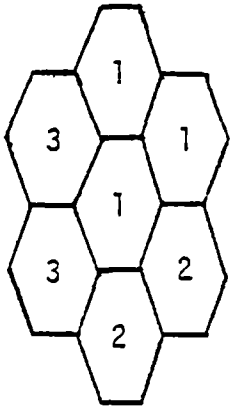
where: A - indicates the species in question
σ - indicates the relative importance of interspersion to juxtaposition for that species
α - indicates the relative importance of juxtaposition to interspersion for that species.

(σ and α may range from 0 to 1, but must sum to 1).
1_A, 2_A, and 3_A indicate exclusion factors

The exclusion factors may also range from 0 to 1, and these must be determined on a specific basis. Notice that in using square cells, the interspersion index is divided by 8, as there are 4 sides and 4 corners which represent possible changes in cover type. The juxtaposition index in this case is divided by 12 as there are 4 corners and 4 sides, and each of the latter is doubly weighted.

APPENDIX II

The Calculation of the Respective Indices Using Hexagonal and Triangular Cell Shapes



Hexagonal Cells

Interspersion

Is = 4

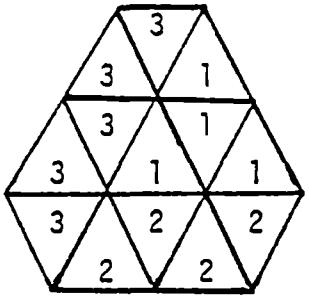
Juxtaposition

Edge Type	Quantity	Quality	Total
1/2	4	.2	0.8
1/3	4	.6	2.4
2/3	0	.4	0.0
			3.2

Spatial Diversity

$$S_D = [(\alpha_A \frac{Is}{6}) + (\sigma_A \frac{Jx}{12})] [1_A \times 2_A \times 3_A]$$

Notice that when using hexagonal cells, no corner cover types are used. Thus, in calculating the spatial diversity index, interspersion is divided by 6, and juxtaposition is divided by 12, as sides are again doubly weighted.



Triangular Cells

Is = 9

Jx

Edge Type	Quantity	Quality	Total
1/2	5	.2	1.0
1/3	6	.6	3.6
2/3	0.0	.4	0.0
			4.6

Spatial Diversity

$$S_D = [(\sigma_A \frac{Is}{12}) + (\alpha_A \frac{Jx}{15})] [1_A \times 2_A \times 3_A]$$

Using triangular cell shapes, the problem becomes more complex as at each corner there are 3 possible changes in cover types along with the 3 possible changes at the 3 sides. Thus, in calculating spatial diversity, the interspersion index is divided by 12, and the juxtaposition index is divided by 15. The latter is again the result of diagonal edges counting as 1 (for a total of 9 diagonal edges, or corner edges) and the edges along sides counting as 2, for a total of (2 x 3) + 9 = 15 possible cover type changes in calculating juxtaposition.

A Technique to Measure Juxtaposition, Interspersion, and Spatial Diversity From Cover Type Maps

by

Gerald H. Cross
Joel Heinen

Department of Fisheries and Wildlife Sciences
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

January, 1982

Leopold (1933) was among the first to recognize the importance of habitat heterogeneity for wildlife by stating that game abundance should increase in situations where various types of food and cover come together. The occurrence of different habitat types within a relatively small area affects wildlife abundance as animals must be able to meet daily and seasonal requirements within restricted spacial arrangements. This is the context in which Leopold defined the term "edge effect."

Wildlife managers are often called upon to evaluate landscapes in terms of their potential to support wildlife populations. Spacial diversity is an important factor and must be considered along with qualitative and quantitative measurements of habitats. Since time and other resources may be limited, the manager needs a rapid and simplified technique for measuring habitat diversity on landscapes of varying sizes and types.

The importance of habitat mixing is recognized in legislation and in policy statements. The Federal Register (1979), for example, specifically mandates that habitat diversity be managed for all federal land. The Forest and Rangelands Renewal Resources Planning Act of 1974 requires that periodic inventories of all natural resources including wildlife habitat be conducted on all forests and rangelands (Hirsch et al. 1979).

A technique which uses measurements of interspersion and juxtaposition as components of a spatial diversity index was described by Mead et al. (1981). Demonstrations of the computerized system used to implement this technique are described by Mead et al. (1981) and Heinen et al. (1981). The purpose of this paper is to describe a manual implementation of this system and demonstrate its use.

Materials and Methods

Input Data

The input data for the use of the system may come from a variety of sources including cover type maps, aerial photographs or satellite imagery. The image or map used to obtain input data must be of appropriate scale to allow identification of specific habitat components for the wildlife population in question. For large game species, satellite imagery alone may be adequate, while larger scaled aerial photographs may be needed to evaluate habitat for small game species (Pettinger et al. 1978).

The identification of biologically meaningful cover types encompassing critical habitat categories (or components) for each population in question is critical. Cover type preference change from species to species and minor alterations may be necessary for species with rather precise habitat requirements. The problem of selecting appropriate maps and identifying cover types needs to be addressed in agreement with an overall management plan for

an area. The solutions rest on the experience and knowledge of the wildlife manager.

Procedures

Input data in the form of categories of habitat are obtained from maps or photographs using a grid overlay. Consideration must be given to the selection of an optimium cell size. The choice should ideally be made on the basis of biological factors such as home range size and patchyness of the landscape. For example, habitat for large herbivores utilizing relatively homogenious landscapes may be analyzed with larger cell sizes than habitat for small game species such as quail or cottontail rabbits (Pettinger et al. 1978).

Symbols or letters representing predominant cover types are placed within each cell on the grid. Discretion must be used in type designation. For example, if an important water source is located within a cell but is not the dominant cover type, it may be necessary to designate a separate cover type which accounts for the presence of water. Type maps must be biologically meaningful to be of use in habitat analysis and the predominance rule in type designation may need modification.

The Calculation of Indices for Interspersion and Juxtaposition

Interspersion is defined by Giles (1978) as the "intermixing of units of different habitat types." According to Mead's criteria, it is calculated by counting the total number of cells surrounding a centroid cell which contain a different cover type category than the centroid cell (Figure I). There are eight possible cover type changes surrounding any cell in a grid. The total number of cover type changes is divided by eight to allow the index to range between 0 and 1.

Figure I

An Example Calculation of Interspersion

A	B	B
B	A	A
A	C	C

$$I_{s1} = \frac{5 - \text{Total number of cover type changes} - 0.625}{8 - \text{Total possible number of ocver type changes} - 0.625}$$

where the letters A, B, and C represent different cover type categories.

Juxtaposition is defined by Giles (1978) as a "measure of the adjacency or proximity of year-around habitat requirements to a site being analyzed for a particular species." Using the method proposed by Mead, relative weighting factors must be assigned representing the importance of different community junctions. These weighting factors are then multiplied by the total number of that type of community junction surrounding a centroid cell and tallied. The total is divided by twelve to allow the index to range between 0.0 and 1.0 (Figure 2). Note that in this case, diagonal edges count as one, while verticle or horizontal edges count as two.

Figure 2

An Example Calculation of Juxtaposition

A	B	B
B	A	A
A	C	C

Edge Type	Quantity	Quality	Total
A/A	4	0.20	0.80
A/B	5	0.50	2.50
A/C	3	0.60	1.80
		Jx =	5.10

Index value = 5.10/12.00 = 0.43

Although the adjacency of two cells containing the same cover type does not represent a true edge, it may be given a weighting factor for the juxtaposition index if large stands of that type are important for the species under consideration.

Spatial Diversity

The spatial diversity (Sd_A) index described by Mead is as follows:

$$Sd_A = [(\nabla_A \frac{Is}{8}) + (\alpha_A \frac{Jx}{12})][1_A][2_A][3_A]$$

where

A = indicates a particular species

∇_A = indicates the relative importance of interspersion

α_A = indicates the relative importance of juxtaposition

1_A, 2_A, 3_A = indicate exclusion factors

Any number of exclusion factors may be used depending on the area and species under consideration. An exclusion factor can be defined as any habitat component which either must or must not be present for a particular species (Mead et al. 1981). They can thus have positive or negative impacts on habitat suitability. An example of a positive exclusion factor may be the requirement of water within 1 mile. If it is present, 1_A may be given the value of 1.0 and thus does not affect the index. If it is absent, a value of 0.0 may be assigned, thus driving the Sd_A index for that parcel of land to zero. A negative exclusion factor may be the presence of anything which impairs the habitat suitability of the area for the species in question. An example may be oil derrick. If it is present, 1_A may be assigned a value of 0.0, thus driving the index to zero.

The numbers assigned for exclusion factors may range between 0 and 1, thus giving the Sd_A index more power.

For example, if free-flowing water (which is highly preferrable) is available for most of the year but only stagnant water (which is less desirable) is available for a three month period, l_A may be assigned a value of 0.7, thus accounting for this seasonality.

Management Application

The headquarters of the Virginia Coast Reserve, owned and operated by the Nature conservancy and located near Nassawodox, Virginia was chosen as the study area for this demonstration for three reasons:

1. Recent (September, 1980), large scale (1:3,900) infrared aerial photography was available.
2. A comprehensive management plan for the area was recently completed (Anderson and Hennessey, 1981).
3. The area is ecologically diverse, containing a mosaic of mixed woodlots, agricultural fields, and salt marsh.

An aerial photo mosaic was compiled from the infrared photography (Figure 3). A cover type map was then drawn on acetate by overlaying the mosaic. Eight cover type categories were designated (Table I). A grid cell system with cells measuring 6.45 cm (one square inch) was then laid over the cover type map. Each cell thus represented 2.7278 ha on the ground at the designated photo scale (1:3,900). There was a total of 220 cells (a matrix of 11 by 20) in

which the indices were calculated. This represents a total of 2159.1 ha on the ground in that study area.

A digit representing the predominant cover type was then placed in each cell. Each cover type may thus be expressed by the frequency of occurrence within the study area on a cellular basis. Notice that using this criteria, cover type category number 7 (hedgerows) has a 0% frequency of occurrence. This is due to the predominance rule used in type mapping. The hedgerows were in all cases too thin to dominate a cell this size. If hedgerows are known to be important for the species in question, this situation may be easily remedied by assigning another category, such as agricultural areas containing hedgerows, thus reflecting this importance.

Edge weighting factors used in the calculation of juxtaposition were arbitrarily assigned for demonstrative purposes (Table II). Index values calculated were interspersion, juxtaposition and spatial diversity for each grid cell. The index values may range between 0.0 and 1.0. This range was divided into three intervals representing areas of low (0.00-0.33), medium (0.34-0.67), and high (0.68-1.00) values for interspersion, juxtaposition and spatial diversity. These ranges are represented by the digits 1 (low), 2 (medium), and 3 (high) on the final grid (see Figures 5, 6, and 7). The total area in each interval for each index is presented in Table III. Average interval

values were calculated for a study area (Table IV) which can be used to evaluate habitats. These values can be used to compare habitat potential in different areas provided that the same criteria are used in type mapping and assigning weighting factors in each area.

Discussion

The use of the system described here is dependent on the management objectives, and should not be considered unless the objectives are well defined. There are a few major advantages inherent in this system such as the relative ease and low cost of implementation. Due to the simplicity of the calculations, general office help could be used to do hand calculations if data sets are large. Systems such as this are also easily programable into micro-computers if these are available, thus minimizing the time investment involved. One major advantage of this system is its versatility. As previously stated, we may use exclusion factors depending on the presence of or distance to important habitat components such as water, or detrimental factors such as some human activities. For organisms which require large homogenious areas, hence low interspersion, the system can be appropriate by simply using large weighting factors for the juxtaposition of cells dominated by the preferred cover type. Juxtaposition may then be given a large importance value in the spatial diversity index with respect to interspersion.

One may wish to consider only an area's ability to support a variety of species, or species complex. In some cases, time and monetary constraints may preclude the repetative implementation of this system for all the species of interest which may occur in an area. In cases such as this, the interspersion index alone may provide the manager with a general feel for habitat diversity in an area.

The information obtained from the indices may be used in various ways. The final product consists of a grid cell system with numbers or characters designating areas of low, medium, or high values for interspersion, juxtaposition or spatial diversity. These areas may be easily located on the ground by overlaying the grid system onto the original type map. If a computerized system is used, a programmer can easily adjust the output so it may be registered to a map of any common scale such as a 7 1/2" U.S.G.S. 1:24,000 quad sheet. Thus the manager has at his disposal information on the location of areas which may represent good or poor habitat for the species or species complex in question.

This information may be used for a variety of purposes. Population census, for example, could be improved by stratifying habitat according to whether it represents a potential for supporting the organism of concern. The information may also be used to aid in decisions such as the placement of clearcuts or other treatments. These may be more optimally placed in areas of low index values if an

increase in interspersion is desirable for one or more game species.

The appropriateness of the input data is probably the major limitation of the system described here. Extremely detailed cover type maps for species-specific analysis may prove inappropriate as many of the categories may be unimportant for a particular species. One way to circumvent this problem and preclude the need to re-map areas for each additional species is to collapse categories from a detailed map in an appropriate manner. This can be accomplished by including all non-important categories into a category designated as "other" (Heinen et al., 1981). In this manner the original (detailed) data base may be used for a variety of species by simply collapsing categories appropriately for each species.

Appropriate use of this system in choosing cover type designations, cell sizes, and weighting factors rests on educated resource managers. There are no simple criteria to follow in making these choices and the information obtained is necessarily subjective. It is not designed to be a detailed habitat analysis system, rather it is a system designed to expediently and economically provide information which may prove to be useful in general management-decision making. More detailed analysis systems relying on extensive ground surveys are needed in situations such as habitat designation for endangered species or problems in pest control.

Table I. The Cover Type Designations and Their Respective Frequencies of Occurrence on the Grid.

Number	Description	Number of Cells	Frequency of Occurrence
1	Water	1	.5%
2	Agricultural Areas	67	30.5%
3	Salt Marsh	45	20.4%
4	Woodlot >50% canopy closure	73	33.1%
5	Woodlot >20% canopy closure ≤50% canopy closure	4	1.8%
6	Open Areas ≤20% canopy closure	25	11.4%
7	Hedgerows	0	0.0%
8	Pine Plantations	5	2.3%
	Total	220	100.0%

Table II. The Edge Weighting Factors Assigned for the* Calculation of Juxtaposition and Spatial Diversity

		COVER TYPE II							
		1	2	3	4	5	6	7	8
COVER TYPE I	1	0.0	0.5	0.4	0.2	0.7	0.6	0.0	0.5
	2		0.1	0.3	0.5	0.6	0.3	0.8	0.7
	3			0.4	0.6	0.7	0.5	0.8	0.5
	4				0.8	0.5	0.7	0.0	0.0
	5					0.6	0.7	0.0	0.4
	6						0.3	0.4	0.7
	7							0.0	0.0
	8								0.3

*The lower half of the matrix is identical to the upper halp and was thus not written (i.e., 2, 7 = 7, 2 = 0.8).

Table III. The Frequencies of Occurrence for Areas of Low, Medium, and High Interspersion, Juxtaposition, and Spatial Diversity.

Interval Number	Designation	Number of Cells in that Interval	Frequency of Occurrence
	Interspersion		
1	Low (0.00-0.33)	60	27.3%
2	Medium (0.34-6.67)	109	49.5%
3	High (0.68-1.00)	51	23.2%
	Total	220	100.0%
	Juxtaposition		
1	Low	65	29.6%
2	Medium	116	52.7%
3	High	39	17.7%
	Total	220	100.0%
	Spatial Diversity		
1	Low	63	28.6%
2	Medium	127	57.7%
3	High	30	13.7%
	Total	220	100.0%

Table IV. The Average Interval Value of Each Index Over the Study Area.*

Indices	Mean Interval Value
Interspersion	$\frac{60(1) + 109(2) + 51(3)}{220} = \frac{431}{220} = 1.96$
Juxtaposition	$\frac{65(1) + 116(2) + 39(3)}{220} = \frac{414}{220} = 1.88$
Spatial Diversity	$\frac{63(1) + 127(2) + 30(3)}{220} = \frac{407}{220} = 1.85$

*Note - A more appropriate method may be to average the row index values rather than the interval number to find average values for an area.

Literature Cited

Anderson, R. R. and G. J. Hennessey. 1981. Natural resource management plan, Brownsville Tract. The Virginia Coast Reserve. The Nature Conservancy.

Federal Registrar. September 17, 1979. Part 219-Planning. Vol. 44, No. 181.

Giles, R. H., Jr. 1978. Wildlife Management. W. H. Freeman and Co., San Francisco.

Heinen, J. T., R. A. Mead, and J. L. Smith. 1981. Site specific maps of juxtaposition and interspersion. S.A.F. National Workshop. 'In-Place Resource Inventories: Principles and Practices.' Orono, Maine.

Hirsch, A., W. B. Krohn, D. L. Schweitzer, and C. H. Thomas. 1979. Trends and needs in federal inventories of wildlife habitat. Forty-fourth N. Am. Wildlife Conf.

Leopold, A. 1933. Game Management. Charles Scribner's Sons. N. Y., London.

Mead, R. A., T. L. Sharik, S. P. Prisely, and J. T. Heinen. 1981. A computerized spatial analysis system for assessing wildlife habitat from vegetation maps. Canadian J. Rem. Sens. 7(1):34-40.

Pettinger, L. R., A. Farmer, and M. Schambergen. 1978. Quantitative wildlife habitat evaluation using high altitude color infrared aerial photographs. Pecora IV. N.W.F. Scientific and Technical Series 3. pp. 335-345.

Pianka, E. R. 1966. Complexity, desert lizards, and spatial heterogeneity. Ecology 47:1055-1059.

Recher, H. 1969. Bird species diversity and habitat diversity in Australia and North America. Am. Nat. 103:75-80.

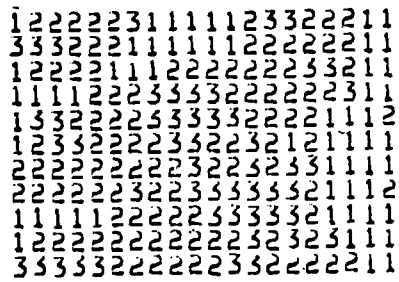


Fig. 5. Interspersion

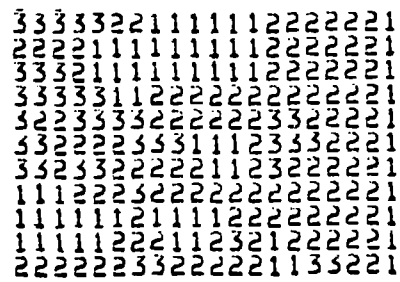


Fig. 6. Juxtaposition

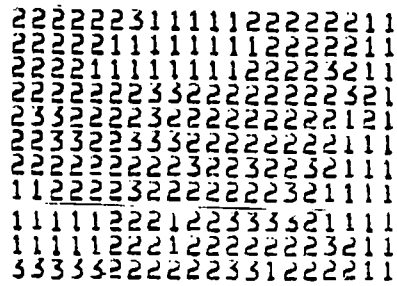


Fig. 7. Spatial Diversity

Simulation of the Effects of Clearcuts on Deer Habitat

by

Joel T. Heinen 1/
and
Roy A. Mead 2/

1/ Graduate Research Assistant, Department of Forestry, School of Forestry and Wildlife Resources, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

2/ Assistant Professor, Department of Forestry, School of Forestry and Wildlife Resources, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

INTRODUCTION

The Resources Planning Act of 1974 requires that periodic assessment of all renewable resources including wildlife habitat be conducted on all federal lands (Hirsch et al., 1979). Legislation such as this has inspired a great deal of research aimed at devising more effective and expedient methods of analyzing habitat. It also imposes restrictions on federal agencies whose major objective may be to manage forests for timber production. These activities must now be legally conducted with regard to imposed secondary objectives such as providing suitable wildlife habitat or recreational opportunities (Federal Register, 1979).

Much recent work has been devoted to the development and application of multiple-use planning models in forestry (Leuschner et al., 1975). These models are designed to estimate the effects of managerial decisions, such as harvesting timber, on a variety of other potential benefits (including recreational opportunities or wildlife production) in the area. Such models have the advantage of allowing managerial decisions to be based on some knowledge of the potential outcome of the many alternatives. Particularly important linear programming models are for timber harvest scheduling (Field et al., 1980). A wildlife habitat analysis system which is readily adapted to computer implementation, such as the one used here, can aid managers in multiple objective decision-making.

The purpose of this study was to test the effects (by simulation) of various clearcutting treatments on the wildlife habitat potential in an area. The wildlife habitat analysis system described by Mead et al. (1981) is used to assess these impacts on the habitat of mule deer (Odocoileus hemionus hemionus) for this demonstration.

DESCRIPTION OF THE HABITAT ANALYSIS SYSTEM

The habitat analysis system described by Mead involves the calculation of interspersion, juxtaposition, and spatial diversity.

CALCULATION OF THE INDICES

Interspersion

Interspersion was calculated for each cell on the study area by counting the total number of cells with a different cover type surrounding the centroid cell and dividing this value by 8 (as there are at most 8 possible cover type changes around any cell). This constrains the index to values between 0.0 and 1.0 (Figure III).

Figure III

An Example Calculation of Interspersion

B	A	A
A	A	C
B	C	C

Is = 5/8 = 0.625

where A, B, and C represent different cover types.

Juxtaposition

Juxtaposition was calculated by summing the number of edges of a particular type surrounding a centroid cell. This is repeated for each edge combination. The total in each case is multiplied by a qualitative weighting factor representing the relative importance of each edge type. These weighting factors may range between 0.0 and 1.0 but they need not sum to one. This sum is then divided by 12 to constrain the index to values between 0.0 and 1.0. Horizontal or vertical edges count as two while diagonal edges count as one (Figure IV).

Figure IV

An Example Calculation of Juxtaposition

B	A	A
A	A	C
B	C	C

Edge Type	Number	Weighting Factor	Total
A/A	5	.3	1.5
A/B	2	.8	1.6
A/C	5	.2	1.0
		Jx =	$\frac{4.1}{12} = .342$

Spatial Diversity

This index is calculated by the following expression:

$$SD = [(\alpha_a \cdot Is) + (\sigma_a \cdot Jx)]$$

where:

a represents species of interest

α_a represents the relative importance of interspersion

σ_a represents the relative importance of juxtaposition

Using the previously described example:

$$SD = [(.5 \cdot 0.625) + (.5 \cdot 0.342)] = 0.4835$$

In this case, interspersion and juxtaposition are considered equally important, so both α_a and σ_a assume a value of 0.5.

Output

The program which calculates each index generates a grid cell system corresponding to that on the original digital input. Each grid cell is thus given a value (ranging between 0.0 and 1.0) for juxtaposition, interspersion, and spatial diversity. For the purposes of this demonstration, the range is divided into thirds to represent areas of low (0.00 - 0.33), medium (0.34 - 0.67), and high (0.68 - 1.00) values for each index. These are represented by the integers 1, 2, and 3, respectively.

These indices are species-specific in that the assignment of relative juxtaposition weighting factors represents the importance of various edge types for a particular species. This system could be used to assess changes in habitat resulting from forestry practices for any organism provided that its habitat requirements are well known in the area of interest. Since the relative importance of specific

edge types may change from region to region for widespread organisms such as deer, these indices are site- as well as species-specific. The indices are calculated on a grid cell basis and are readily adapted to computerized systems. They may thus be easily incorporated into more comprehensive multiple use planning schemes. One of the major advantages of this system is its flexibility.

STUDY AREA AND DATA

The data for this study were derived from a Landsat MSS image of the Rampart Hills Quadrange, San Juan National Forest, Colorado (Figure I). Each grid cell on this image represented approximately 3 acres on the ground. The northwest section of this quadrangle, totalling 1800 acres (600 pixels), was considered for this demonstration (Figure II). The original 19 cover types designated on the area were collapsed into seven categories. These include willow, grass, conifer, shrub, oak, aspen, and other. Those categories present on the original imagery which were not considered important habitat components for deer were all included in the category designated as "other".

The specific weighting factors chosen for the importance of various edge types for deer were derived from recommendations of Forest Service personnel (Cook, 1981, personal comm.) (Table 1).

TABLE 1

Juxtaposition Weighting Factors for the Collapsed Categories

	Willow	Grass	Conifer	Shrub	Oak	Aspen	Other
Willow	0.00	0.75	0.50	0.25	0.125	0.00	0.00
Grass		0.00	0.00	0.00	0.00	0.05	0.00
Conifer			0.00	0.00	0.00	0.025	0.00
Shrub				0.00	0.00	0.00	0.00
Oak					0.00	0.00	0.00
Aspen						0.00	0.00
Other							0.00

SIMULATION OF CLEARCUTS

This simulation was conducted by first assuming that the managerial objective was to cut 432 acres of timber of any type within the 1800 acre study area. This number of acres cut was chosen for the purposes of this demonstration as it is easily divisible by four to decrease clearcut size. These clearcuts could be various shapes and sizes, so long as a total of 432 acres, or 144 cells were affected. Each clearcut prescription was simulated by changing the cells affected by the cutting operation from their original forest cover type designation to a designation representing grasslands. The implicit assumption made was that following clearcutting, the major floral component in the area would be grasses and forbs.

After each clearcut was simulated, calculations for interspersion, juxtaposition, and spatial diversity were repeated. Total cell counts for high, medium, and low index values for each treatment and the control were then tallied and compared.

The treatments applied to the area included 3 different size categories for each of two different shapes of clearcuts (Table 2).

TABLE 2

Description of Treatments

Treatment Number	Number of Cuts in Area	Shape of Cuts	Number of Cells Per Clearcut	
1	1	Square	144	(Large)
2	1	Rectangle	144	
3	4	Square	36	(Medium)
4	4	Rectangle	36	
5	16	Square	9	(Small)
6	16	Rectangle	9	

Treatments 1 and 2 consisted of 1 432 acre clearcut. Although this represents an unrealistically large clearcut, it is considered valid for the sake of comparison. Treatments 3 and 4 consisted of 4 clearcuts, each totalling 108 acres (36 cells). Treatments 5 and 6 consisted of 16 27 acre clearcuts. Treatments 1, 3, and 5 were simulated using square clearcuts and treatments 2, 4, and 6 were simulated using rectangular clearcuts. This method thus allows assessment of both size and shape of the clearcuts on the resultant indices over the entire area.

RESULTS

The results indicate an effect from both size and shape of the clearcut prescriptions on the interspersion index for the area. As the size of the clearcut was decreased, the number of cells classed as low also decreased. Conversely, the number of cells classed as either medium or high interspersion increased with decreased clearcut size. For the same sized clearcuts, rectangular clearcuts yielded more medium and high values and less low values of interspersion than did square clearcuts (Table 3).

CELL COUNTS

TABLE 3

Interspersion Total for the Area by Treatment

			Treatment					
		No Treatment	1	2	3	4	5	6
Low	# Cells*	205	267	247	212	181	162	136
Medium	# Cells	263	238	250	262	292	316	317
High	# Cells	132	95	103	126	127	122	147

Total # of Pixels = 600

Total # of Acres = 1800

* # Acres = 3 x # Pixels

The adjusted interspersion index for the whole area for each treatment was calculated with the following expression:

ADJUSTED Is INDEX = 1 · (# Cells classed as low interspersion) +
2 · (# Cells classed as medium interspersion) +
3 · (# Cells classed as high interspersion).

The adjusted index allowed for the relative comparison of overall index values for the entire area under each treatment. Placing these values in a 2 x 3 matrix illustrated the effect of both the size and the shape of the clearcut treatment (Table 4).

TABLE 4

Adjusted Interspersion Index
for the 6 Treatments

Clearcut Shape \ Clearcut Size	Large	Medium	Small	Total by Shape
Square	1028	1114	1160	3302
Rectangle	1056	1146	1211	3414
Total by Size	2084	2260	2371	6715

An adjusted interspersion index of 1127 was calculated using no treatment. This index increased over the entire area as clearcut sizes decreased and changed in shape from square to rectangular.

The juxtaposition index values for each treatment and the control were consistently low throughout the entire area. There is, therefore, no difference between any of the treatments for juxtaposition. This is a result of the weighting factors assigned (Table 1) and will be discussed elsewhere (see Discussion). Since the juxtaposition values are all low, and since juxtaposition was equally weighted with interspersion in the calculation of spatial diversity (both α_a and σ_a = 0.5), the spatial diversity values are lower than are the interspersion values. For any treatment, there are far more cells classed as having low spatial diversity than low interspersion (Table 5). There are no cells having high spatial diversity values using any treatment.

TABLE 5

Spatial Diversity Total for the Area by Treatment

		No Treatment	Treatment 1	2	3	4	5	6
Low	# Cells	464	501	497	473	473	477	452
Medium	# Cells	136	99	103	103	127	123	148
High	# Cells	0	0	0	0	0	0	0

Despite the generally lower spatial diversity values in comparison to those obtained from the interspersion calculations, the adjusted totals for spatial diversity for the area showed similar effects of clearcut size and shape (Table 6). Spatial diversity over the entire area increased as the size of the clearcuts decreased, and as the shape of the clearcuts changed from square to rectangular.

TABLE 6

Adjusted Spatial Diversity Index
for the 6 Treatments and 1 Control

Clearcut Size / Clearcut Shape	Large	Medium	Small	Total by Shape	
Square	699	727	723	2149	No Treatment
Rectangle	703	727	748	2178	736
Total by Size	1402	1454	1471	4327	

DISCUSSION

The results of this simulation indicated that smaller clearcuts with shapes that tend to increase perimeter generally created an increase in interspersion and spatial diversity (as defined by Mead). Similar results would also be expected for juxtaposition, as the grassland community resulting from clearcuts is an important habitat component for deer. A comparison between treatments is not possible for the juxtaposition index as the entire area for each treatment yields low values. This is a result of the weighting factors used to calculate this index (Table 2). The weighting factors in descending order include willow with grass, conifer, shrub, and oak, respectively. There are no cells within the study

area predominated by willow. This does not necessarily indicate that no willow is located in the area; rather, it indicates that willow was not aggregated enough to show up as a distinct class in any sampling units on the Landsat imagery. This represents a limitation of the input data but in no way negates the results obtained in this study. An effect of both clearcut size and shape is observed for both spatial diversity and interspersion. That trends in the adjusted spatial diversity index are less dramatic than those in the interspersion index is merely a result of the low juxtaposition.

The index values for the study area (no treatment) were higher than those obtained from treatments 1 through 3 for interspersion and treatments 1 through 4 for spatial diversity. This indicated that the area was initially composed of a diverse mixture of cover types, and the large clearcuts imposed by treatments 1 through 4 tended to decrease this mixture. In large homogeneous woodlots, clearcutting operations may be expected to increase interspersion regardless of the size of the cut. Juxtaposition would increase only if there are relatively large weighting factors assigned for the adjacencies of the forested and grassland communities which resulted from the clearcut. Spatial diversity could increase or decrease depending on the relative importance values assigned for interspersion (α_a) and juxtaposition (σ_a).

The clearcutting treatments were placed evenly and systematically throughout the entire area for this demonstration. The results of such

a technique may differ somewhat if cuts are preferentially placed in one section of an area vs. another. This would depend on the homogeneity and the category of cover types in one section as opposed to another and is thus a result of the area in question. When this is taken into account, treatments may be simulated in such a way as to increase the index values for certain species depending on initial management goals.

SUMMARY AND CONCLUSIONS

This study demonstrated the use of simulating clearcutting prescriptions to assess the impact on wildlife habitat. Such simulation procedures allow managerial decisions to be based on an estimated outcome of any option available, and may be used to meet multiple use objectives imposed by recent legislation. The results indicated that as clearcut sizes decrease and assume shapes which increase the perimeter there is a trend toward better habitat for deer. The habitat analysis system described by Mead et al. (1981) and used in this demonstration has great potential as a submodel in more comprehensive planning models. It is easily adaptive to computer analysis and can be used for many species in an area with minor modifications in cover type designations and weighting factors.

LITERATURE CITED

Cook, D. 1981. Personal Communication. Wildlife Biologist. U. S. Forest Service, San Juan National Forest. Colorado.

Federal Register. 1979. Rules and Regulations. Part 219. Planning. 44(181):J3976-992.

Field, R. C., P. E. Dress, and J. C. Fortson. 1980. Complementary Linear and Goal Programming Procedures for Timber Harvest Scheduling. Forest Sci. 26(1):121-133.

Hirsch, A., W. B. Krohn, D. L. Schweitzer, and C. H. Thomas. 1979. Trends and Needs in Federal Inventories of Wildlife Habitat. Forty-Fourth North American Wildlife Conference.

Leuschner, W. A., J. R. Porter, M. R. Reynolds, and H. E. Burkhart. 1975. A Linear Programming Model for Multiple-use Planning. Can. J. For. Res. 5(3):485-491.

Mead, R. A., T. L. Sharik, S. P. Prisley, and J. T. Heinen. 1981. A Computerized Spatial Analysis System for Assessing Wildlife Habitat from Vegetation Maps. Can. J. Rem. Sensing 7(1):34-40.

SUMMARY

This study has thus far proceeded with two main emphases. The first includes the applied work described in the two drafts and one published paper included here. The second emphasis consists of the basic research proposed in the thesis working plan. This includes a sensitivity analysis of the habitat evaluation system proposed by Mead et al. (1981).

The applied aspects of this study describe many potential uses of this system with different types of input data for automated (over large regions) or manual (over small areas) habitat analysis. An important thrust of the applied research is the utility of the system for meeting recent legislative mandates imposed on resource managers.

The basic research proposed in the thesis working plan is now underway. It is hoped that as results become available, specific recommendations can be made concerning the use and limitations of Mead's system. A procedural manual may then be written describing the use of weighting factors, classification accuracy and the level (or specificity) of classification. Recommendations may also be made concerning cell sizes and cell shapes when these are changeable as in manual analysis.

APPENDIX I

SITE SPECIFIC MAPS OF JUXTAPOSITION AND SPATIAL DIVERSITY [1/]

Joel T. Heinen, Roy A. Mead, and James L. Smith [2/]

Abstract.--This paper reports on the progress of an on-going study being conducted at Virginia Tech in cooperation with the U. S. Forest Service. Interspersion, juxtaposition and spatial diversity indices for Abert squirrel were calculated for each three acre grid cell on the Rampart Hills Quadrangle, located in south-western Colorado.

1/ Paper presented at SAF National Workshop "In-Place Resource Inventories: Principles and Practices". [University of Maine, Orono, August, 1981.]

2/ The authors are respectively Graduate Research Assistant and Assistant Professors in the Department of Forestry, VPI & SU, Blacksburg, VA.

INTRODUCTION

Environmental issues have lead to recent legislation concerned with wildlife habitat evaluation. The Forest Service has been the focus of much of this legislation. The Forest and Rangelands Renewable Resources Planning Act of 1974 requires that periodic evaluation of all renewable resources, including wildlife, be conducted on all Federal lands (Hirsch et al., 1979). Various pieces of legislation mandated that the Forest Service and other federal agencies manage for habitat diversity (Federal Register, 1979), because greater habitat diversity generally leads to greater numbers of viable wildlife species populations within an area (Soule' and Wilcox, 1980).

The need for the development of techniques which rapidly and economically measure habitat diversity thus becomes apparent. Such a system was produced by Mead et al. (1981). This system is both site and species specific, and is based on the concepts of interspersion and juxtaposition. Interspersion may be defined as the "intermixing of units of different habitat types" and juxtaposition may be defined as a "measure of the adjacency or proximity of year-around habitat requirements to a site being analyzed for a particular species (Giles, 1978)". The spatial diversity index described by Mead is a function of interspersion, juxtaposition and any number of exclusion factors.

This study represents a trial of the habitat evaluation system proposed by Mead et al. (1981). The test was conducted on Abert squirrel (Sciurus aberti) in an area within the San Juan National Forest in southwestern Colorado.

METHODS

Study Area

One 7-1/2 minute USGA topographic quadrangle from the San Juan National Forest was selected to test the system proposed by Mead. The Rampart Hills Quadrangle, located in the western portion of the forest, was suggested by the Forest Service as the test site because a cellular (3 acres per grid cell) data base was available for this area. Also, several other remote sensing and habitat evaluation studies were being conducted in this area, and local wildlife biologists were willing to assist in estimating the parameters required by Mead's procedure. The study area contained 136 rows of cells by 90 columns, or 12240 three-acre grid cells, each with a predominant cover type designation.

Spatial Diversity Evaluation System

The habitat evaluation system proposed by Mead requires that cellular cover type information be available. Interspersion, juxtapositon and spatial diversity values are calculated for each cell using its cover type designation, and the cover type designation of the eight surrounding cells. Computer maps of the areas of interest can be easily and rapidly produced for many species, seasons and management strategies.

According to the criteria described by Mead, interspersion for each cell is the total number of cells around that cell whose cover type designation is different from that of the cell of interest. The

juxtaposition index for each cell is calculated by multiplying a weighting factor reflecting the relative goodness of each community edge type for the species in question by the total number of cellular edges of that particular type surrounding the cell of interest. In calculating juxtaposition, horizontal and vertical edges count as two, while diagonal edges count only as one.

The spatial diversity index is a weighted average of interspersion and juxtaposition, and can be mathematically formulated as:

$$Sd_A = [(\sigma_A \frac{Is}{8}) + (\alpha_A \frac{Jx}{12})] [1_A \times 2_A \times 3_A]$$

where Sd_A = spatial diversity for a particular species

Is = interspersion for a particular species

Jx = juxtaposition for a particular species

σ_A = relative importance of interspersion

α_A = relative importance of juxtaposition

$1_A, 2_A, 3_A$ = exclusion factors for a particular species

Note that the interspersion index is divided by 8, and the juxtaposition index by 12. These divisors force the two indices to range between 0 and 1. The spatial diversity component weights, σ_A and α_A, range from 0 to 1 also, but they must sum to 1. Exclusion factors were not considered in this evaluation.

The Forest Service contracted with the Lockheed Corporation to produce a 1978 cover type map of the San Juan National Forest using Landsat MSS spectral data. The final product was completed in 1980, and included 19 cover types. The original 19 categories are presented in Table 1, along with their respective symbols used as inputs for this study. Of the 19 possible cover types, 13 occurred on the Rampart Hills Quadrangle.

The cover types described were collapsed into four broad categories (Table 2). This was accomplished in view of the habitat requirements of Abert squirrel, as described by Forest Service personnel.[3/] This species was considered for the demonstration because its habitat requirements were easily defined. The weighting factors for the various edge combinations used to compute the juxtaposition index were also derived from the recommendations and information provided by the Forest Service (Table 3).

The spatial diversity index is a function of interspersion and juxtaposition. In the calculation of spatial diversity, one must obtain values indicating the relative importance of these two components. Upon the recommendation of the local Forest Service personnel, the values of

σ_A = 0.25 (weight for interspersion) and

α_A = 0.75 (weight for juxtaposition) were assigned.

3/ Dave Cook, 1981, Wildlife Biologist, San Juan National Forest

Table 1. Classification system devised by Lockheed Corporation for the cover types present in the San Juan National Forest, Colorado.

Verbal Land Cover (Lockheed)		Rempart Hills-VPI Code
01	Water	19 25
02	Cottonwood/Aspen	05 07 06 17
03	Ponderosa Pine	23 16
04	Spruce/Fir	24
05	Doug/Fir	09 18
06	Ponderosa Pine/Oak	--*
07	Conifer/Aspen	08
08	Aspen/Conifer	01
09	Oak	02 03 04
10	Pinyon Juniper	10 11 --
11	Oak/Conifer	--
12	Rock	15 24
13	Willow	--
14	Mixed Sagebrush	--
15	Mesic Meadow	--
16	Grass	21 -- 14
17	Alpine	13 --
18	Rocky/grass	22 12 --
19	Other	-- --

*A slash in the last column indicates that thatparticular cover type category was not present on the Rampart Hills Quadrangle.

Table 2. Strategy for collapsing the original 19 cover type categories for Abert squirrel.

	Pine (01)	Oak (02)	Grass (03)	Other (04)
Lockheed Categories	Ponderosa Pine (03))	Oak (09)	Grass (16) Alpine (17) Rocky/grass (18)	Water (01) Rock (12) Cottonwood/Aspen (02) Spruce/Fir (04) Doug/Fir (05) Conifer/Aspen (07) Aspen/Conifer (08) Pinyon Juniper (10)

Table 3. Edge weighting factors for the collapsed categories.*

	Pine	Oak	Grassland	Other
Pine	0.5	0.25	0.25	0.00
Oak		0.00	0.00	0.00
Grassland			0.00	0.00
Other				0.00

*Only the upper portion of the matrix was indicated since it is symmetric.

Map Production

Values for juxtaposition, interspersion and spatial diversity were calculated for each cell on the Rampart Hills Quadrangle using a FORTRAN IV computer program. Maps were prepared of a sample of the quadrangle (rows: 56-95, columns: 2-41) using a Versatec Electrostatic plotter. A sample was utilized because the available Versatec plotter only handles 10 inch paper.

RESULTS AND DISCUSSION

Interspersion maps of the study area were produced for two different sets of input data. Figure 1 was created using all of the

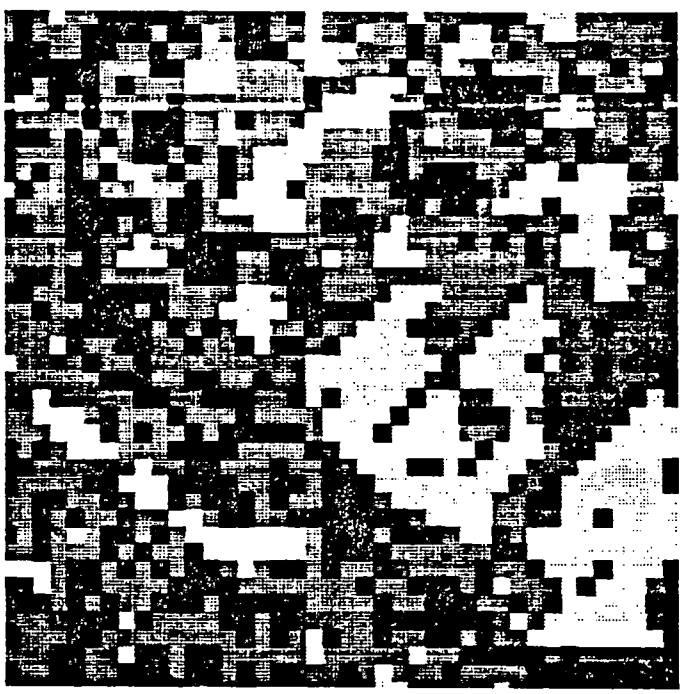


Figure 1. Interspersion map using all 19 categories for the Rampart Hills Quadrangle.

13 original cover types which occurred in the study area. The second interspersion map (Figure 2) was produced using the four collapsed categories. The light, medium and dark tones represented areas of low (0.00-0.33), moderate (0.33-0.67), and high (0.67-1.00) interspersion, respectively. The differences in the maps is wholly attributable to the cover type category collapsing scheme used for Abert squirrel. Naturally, fewer initial cover types (on the same area) will result in less mixing of cover types, i.e., lower interspersion. However, both maps indicate that there is a good mixture of cover types in this area. This is sometimes taken to be an indication of good overall wildlife habitat quality.

Using Mead's definition, each of the cells in the Rampart Hills Quadrangle was found to have a low value for juxtaposition (< 0.33) for Abert squirrel (Figure 3). This is a direct result of the high weighting factor assigned for the adequacy of pine-dominated grid cells. In the entire study are (approximately 30,000 acres), only 300 acres were classed as ponderosa pine. Even this may be optimistic, as Abert squirrel actually prefers older, denser pine stands. The age/stocking information was not available, so all pine cells were assumed to be suitable for the species in question. It is evident that this study area does not contain the communities preferred by Abert squirrel.

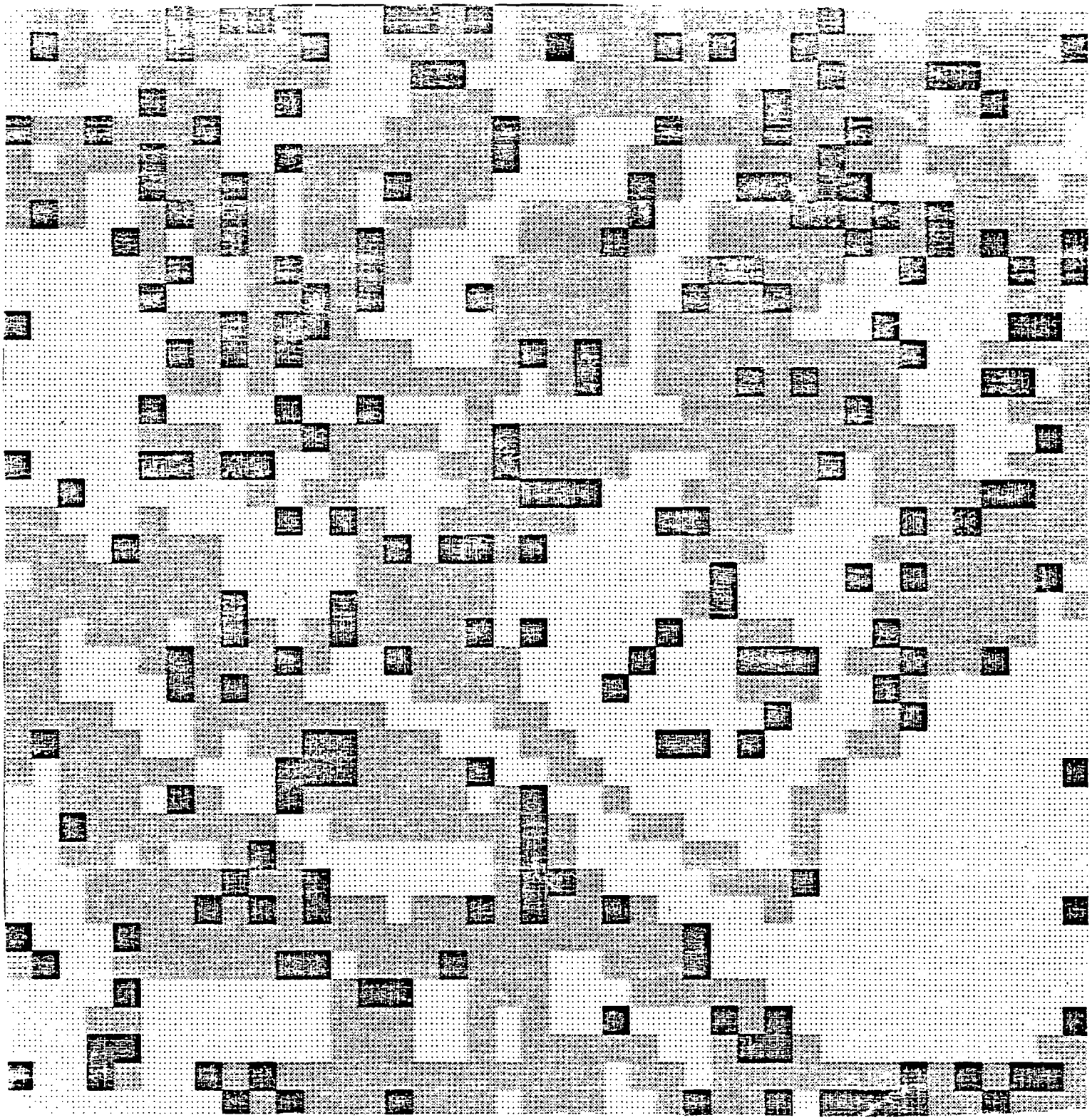


Figure 2. Interspersion map using the 4 collapsed categories for the study area.

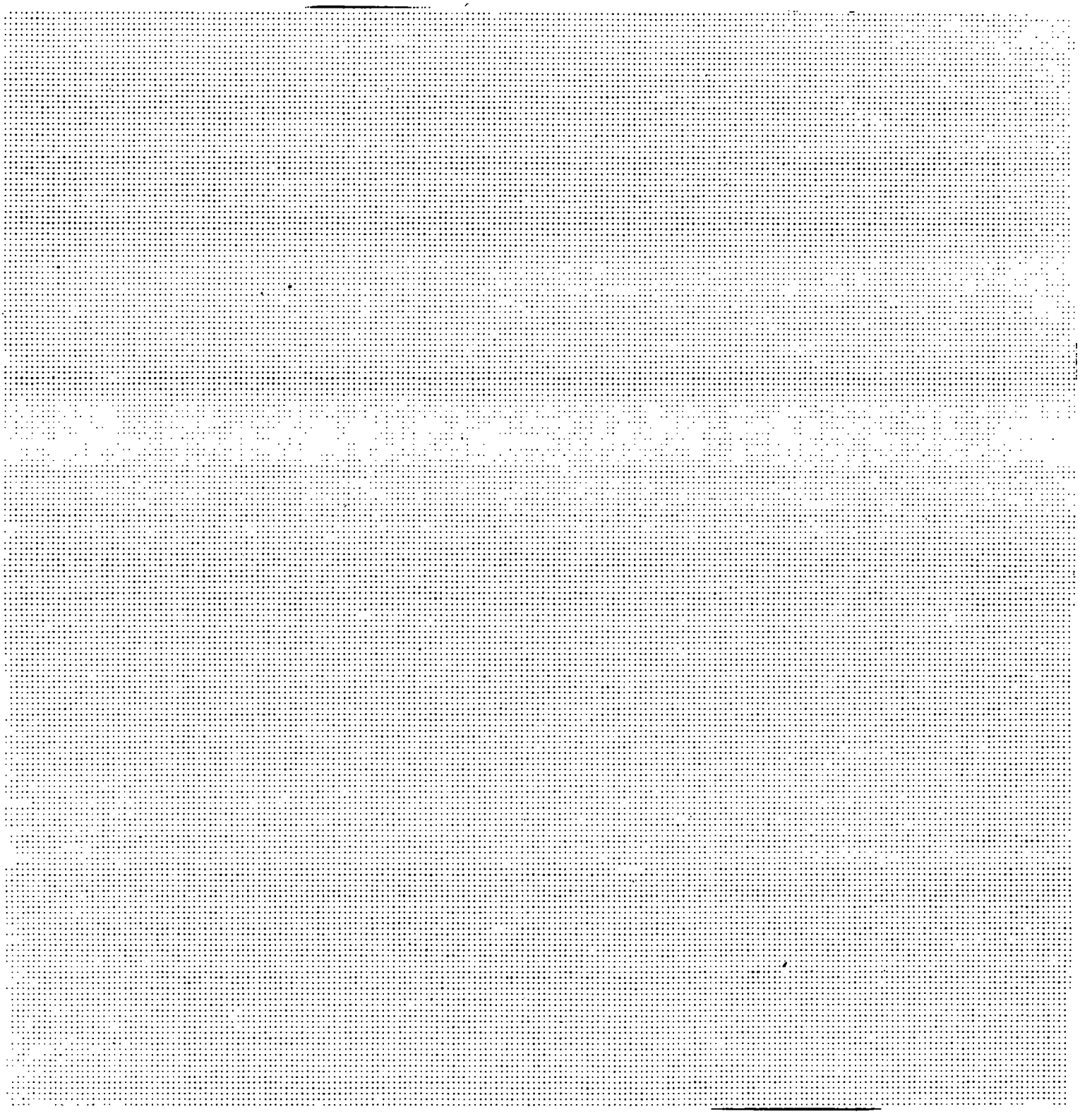


Figure 3. Juxtaposition map of the study area for Abert squirrel.

Each of the 12240 three-acre cells in the Rampart Hills Quadrangle, with the exception of two (classed as moderates), had a low value for the spatial diversity index (Figure 4). This is a result of the relative importance of juxtaposition (0.75) compared to interspersion (0.25). The specific communities preferred by Abert squirrel were deemed to be much more important than a mix of many communities. Thus, the general conclusion is that few sites within the study area are good (preferred) habitat for Abert squirrel.

SUMMARY AND CONCLUSIONS

The utility of Mead's habitat evaluation system was demonstrated for Abert squirrel on the Rampart Hills Quadrangle in southwestern Colorado. As only a small part of a larger habitat evaluation system, the procedure defined by Mead could be used to rapidly and easily test the effects of various management strategies, seasons, natural disasters, etc. on habitat quality for many species.

Site- and species-specific maps of juxtaposition, interspersion and spatial diversity were produced via a computer. Although a good mix of cover types was available, they were not the types preferred by Abert squirrel. Thus, the area was found to be generally poor habitat for the species examined.

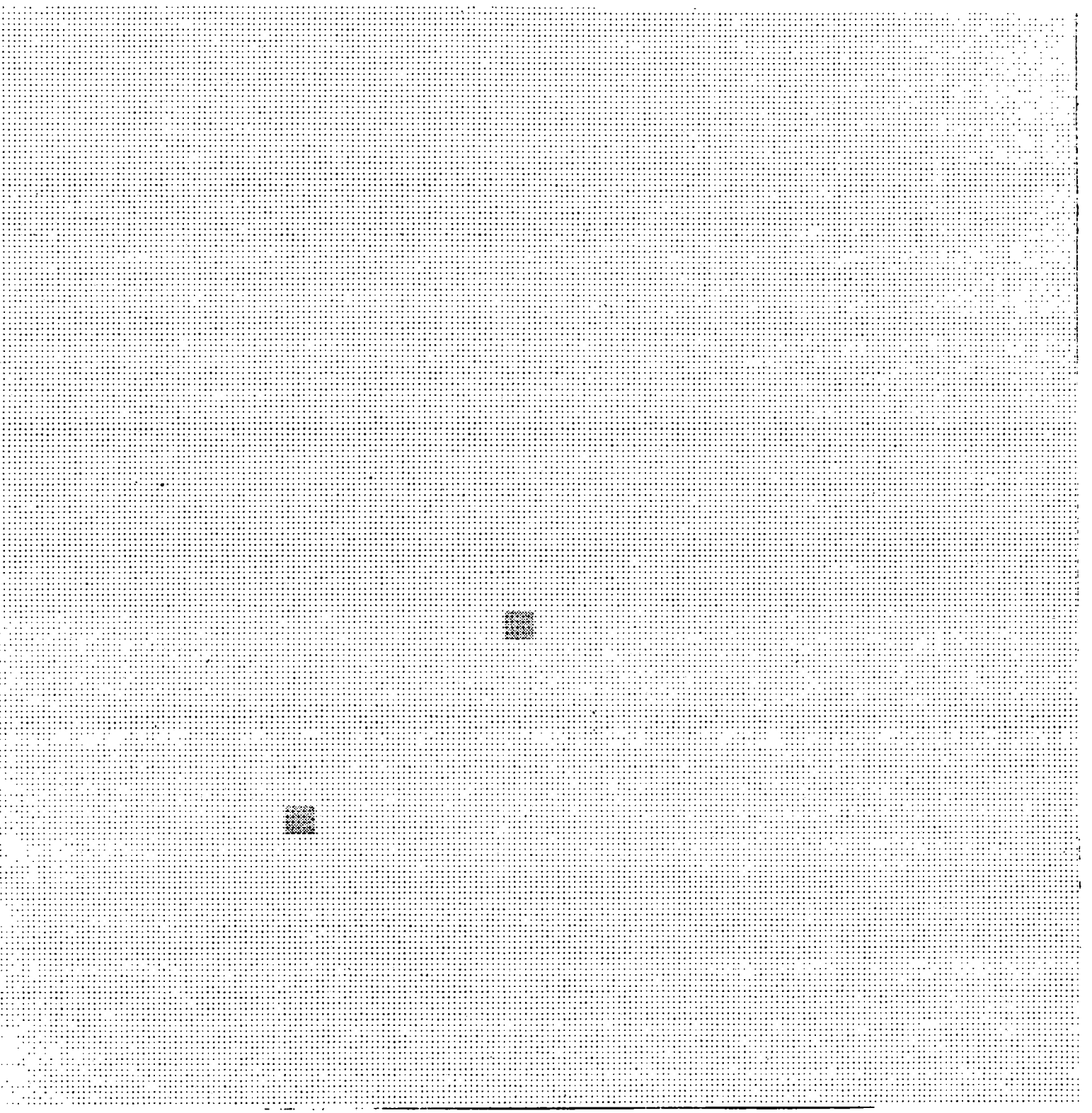


Figure 4. Spatial diversity map of the study area for Abert squirrel

ACKNOWLEDGMENTS

The authors would like to thank Steve Prisley for writing the original computer programs which calculate the indices. Thanks also are given to Dave Cook of the San Juan National Forest for his many recommendations. This work was funded by the Forest Service under Cooperative Agreement Number 13-1134.

LITERATURE CITED

Federal Register. 1979. Part 219 - Planning. Vol. 44, No. 181. Sept. 17, 1979.

Giles, R. H. 1978. Wildlife Management. W. H. Freeman and Co., San Francisco. Pages 156-159.

Hirsch, A., W. B. Krohn, D. L. Schweitzer, and C. H. Thomas. 1979. Trends and Needs in Federal Inventories of Wildlife Habitat. Forty-Fourth North American Wildlife Conference.

Mead, R. A., T. L. Sharik, S. P. Prisley, and J. T. Heinen. 1981. A computerized spatial analysis for assessing wildlife habitat from vegetation maps. Tech. Papers. Am. Soc. of Photogramm. 47th Annual Meeting. 212-220.

Soule, M. E. and B. A. Wilcox. 1980. (Eds.). Conservation Biology - An Evoluation-Ecological Perspective. Sinauer Associates, Inc. 395 pp.